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INDEPENDENT PRODUCTION COST ESTIMATE: XM1 TANK MAIN ARMAMENT EVALUATION.

NOV 77

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TECHNICAL REPORT.

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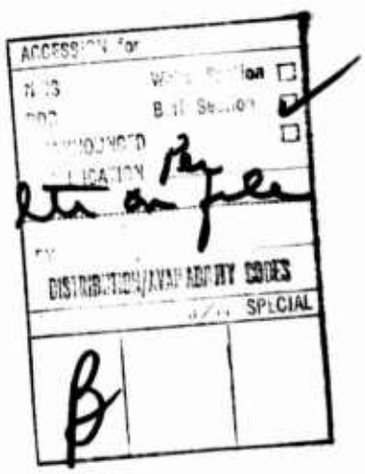
ABSTRACT

Parametric estimating of the recurring investment costs for tank main armament systems has recently been improved with new modeling techniques, as well as with an improved data base. This report illustrates the use of such estimating techniques as prepared for the XM1 Tank Main Armament Evaluation (TMAE). It also expands parametric estimating techniques to white phosphorous (WP), antipersonnel (APERS), and target practice discarding sabot (TPDS) rounds. over to p. 1



INDEPENDENT PRODUCTION COST ESTIMATE:

XM1 TANK MAIN ARMAMENT EVALUATION

November 1977

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I. INTRODUCTION

A. Purpose:

As discussed in reference 12, the requirement for an Independent Unit Production Cost (IUPC) was first presented to DRSAR-CPE by informal tasking, 26 Sep 77. The purpose of the IUPC is to provide a test of reasonableness for the engineering cost estimates included in the Cost, Schedule, Logistics, and Standardization (CSLS) impact portion of the XM1 tank main armament evaluation (TMAE) for the XM1 Project Manager. As a test of reasonableness, maximum reliance is placed upon use of parametric estimating techniques. The parametric procedures used emphasize the interrelation between US design philosophy and manufacturing cost. No adjustment has been made to compensate for such differences between the various options, thus the costs can be said to represent Americanized versions of the foreign guns and ammunition for the 120mm options. Reference 1 is used to estimate ammunition parametrically. Where data are available, current production experience is used. Only four of the 24 rounds were not estimated parametrically. The M68 cannon and breech assembly were provided at latest funded cost. The two remaining weapons were estimated parametrically using the data base provided with reference 3.

B. Scope:

The options covered in this study are: the US option using the 105mm M68 gun, the United Kingdom's ~~(UK)~~ 120mm rifled gun, and the Federal Republic of Germany's GE 120mm smoothbore gun. Each gun is furnished an appropriate family of ammunition. The scope of the weapon ~~IUPC~~ is limited to the recurring unit manufacturing cost of the cannon and breech assemblies including engineering and product assurance support, but excluding first destination transportation. The ammunition cost excludes the cost of Government engineering and quality assurance support, but includes first destination transportation.

C. Organization of the Study:

The study results at the summary level are shown and discussed in Section II. The detailed input data in support of the summary are at Section III. Finally, detailed discussion of estimating methodology is provided in Section IV. Unless otherwise noted, all costs are stated in FY 77 dollars.

D. Acknowledgements:

This study could not have been completed without the suggestions and assistance provided by the following individuals. Mrs. Marcia Waldron was responsible for the typing of most of the study, and her meticulous attention to detail and precise rendering of complicated formulas was greatly appreciated. Mrs. Ellen Trollan, Mrs. Paula Gomez, and Mrs. Marlene Manning provided additional typing and clerical support, without which the study could not have been completed.

II. STUDY RESULTS

A. Tables.

Tables 2 through 6 contain study results.

TABLE 1

XM1 TANK MAIN ARMAMENT EVALUATION

GUN AVERAGE UNIT COSTS FY 77 $

UK 120mm	$ 21,600
GE 120mm	$ 22,400
US 105mm	$ 14,500 *

* US cost based on most recent funded order.

Gun costs rounded to nearest hundred dollars.

TABLE 2

XM1 TANK MAIN ARMAMENT EVALUATION

COMPLETE ROUND AVERAGE UNIT COSTS FY 77 $

UK 120MM

PRODUCTION ENDING AS OF YEAR	MP	APFSDS	WP/SMOKE	APERS	TPFSDS	MP-TP
1983	$213	$412	-----	-----	$222	$143
1985	198	405	$167	$597	215	123
1994	186	401	153	524	210	109
2007	(No production after 1994)		148	(No production after 1994)	209	105

Costs rounded to nearest dollar.

TABLE 3

XM1 TANK MAIN ARMAMENT EVALUATION

COMPLETE ROUND AVERAGE UNIT COSTS FY 77 $

GE 120MM

PRODUCTION ENDING AS OF YEAR	MP	APFSDS	WP/SMOKE	APERS	TPFSDS	MP-TP
1983	$214	$424	----	-----	$225	$139
1985	198	417	$167	$597	219	119
1994	185	412	153	524	214	105
2007	(No production after 1994)		148	(No production after 1994)	213	101

Costs rounded to nearest dollar.

TABLE 4

XM1 TANK MAIN ARMAMENT EVALUATION

COMPLETE ROUND AVERAGE UNIT COSTS FY 77 $

US ONLY 105MM

PRODUCTION ENDING AS OF YEAR	MP	APFSDS	WP/SMOKE	APERS	TPFSDS	MP-TP
1983	$144	$270	$125 *	$370 *	$169	$90
1985	137	267	125 *	370 *	167	84
1994	133	265	125 *	370 *	165	78
2007	(No production after 1994)		125 *	(No production after 1994)	163	76

* Latest procurement costs adjusted to FY 77 $.

Costs rounded to nearest dollar.

TABLE 5

XM1 TANK MAIN ARMAMENT EVALUATION

COMPLETE ROUND AVERAGE UNIT COSTS FY 77 $

US PHASEOUT 105MM

PRODUCTION ENDING AS OF YEAR	MP	APFSDS	WP/SMOKE	APERS	TPFSDS	MP-TP
1983	$148	$270	$125 *	-----	$170	$90
1985	141	268	125 *	-----	168	86
1994	138	267	125 *	-----	167	83
2007	(No production after 1994)					

* Latest procurement costs adjusted to FY 77 $.

Costs rounded to nearest dollar.

TABLE 6

XM1 TANK MAIN ARMAMENT EVALUATION

TOTAL AMMUNITION COST PER OPTION FY 77 $ IN MILLIONS

	MP	APFSDS	WP/SMOKE	APERS	TPFSDS	MP-TP	TOTAL
US							
105MM	$125.3	$270.9	$65.5	$ 5.5	$1160.3	$ 948.8	$2576.3
UK							
120MM	$175.5	$486.3	$81.6	$18.8	$1208.1	$1073.3	
105MM	61.9	103.5	8.7	----	385.5	108.0	
Total	$237.4	$589.8	$90.3	$18.8	$1593.6	$1181.3	$3711.2
GE							
120MM	$174.9	$500.6	$81.6	$18.8	$1230.7	$1031.7	
105MM	61.9	103.5	8.7	----	385.5	108.0	
Total	$236.8	$604.1	$90.3	$18.8	$1616.2	$1139.7	$3705.9

B. Discussion of the Results

1. General:

a. The unit costs shown in Table 1 indicate that the greater weight of the 120mm GE cannon and breech assembly overbalances the effects of the higher momentum levels generated by the UK ammunition.

b. Overall, the differences between the two 120mm ammunition options are insignificant. The UK multipurpose and matched practice rounds cost slightly more than the GE equivalents because of higher propellant and transportation costs. The GE APFSDS round offsets this however, because of the use of a heavier penetrator.

2. A number of potential conditions in the ammunition estimates require sensitivity analysis. They are: inflation of tungsten prices, design of the multipurpose round, use of stick vs granular propellant, and use of a DU penetrator rather than tungsten for the 120mm options.

a. Inflation of Tungsten Prices - The 1.17 inflator provided in the referenced inflation guidance (references 4 and 5) understates the inflation of tungsten prices that has actually taken place since FY 75. The reference 1 FY 75 cost of $10.73, when compared to a FY 77 quote of $13.75 received by LCWSL, results in a more correct inflator of 1.28.

The effect this has on the APFSDS round is as follows:

(1) The German 120mm APFSDS.

	Proj. Metal Parts	Total Round	Total Program
Adjusted Est.	$246.089	$432.863	$629.0M
Original Est.	225.619	412.393	604.1M
% Increase	9.1%	5.0%	4.1%

(2) The British 120mm APFSDS.

	Proj. Metal Parts	Total Round	Total Program
Adjusted Est.	$231.841	$419.895	$613.3M
Original Est.	212.556	400.610	589.8M
% Increase	9.1%	4.8%	4.0%

b. Design of the Multipurpose Round - This round may incur cost increases resulting from designs still under consideration which will effect the cost of explosive fill and LAP. The resulting increases could accumulate to 25 percent and are as follows:

	US 105mm	UK 120mm	GE 120mm
Estimated unit cost	$132.630	$186.101	$185.436
plus 25 percent	33.158	46.525	46.359
New unit cost	$165.788	$232.626	$231.795
Total program increase	$156.7 million	$219.4 million	$218.6 million

c. Use of Stick vs Granular Propellant - In order to retain the ballistic integrity of the German 120mm MP and MP-TP rounds, personnel at LCWSL agree that the stick propellant should be used instead of granular propellant. The parametric estimating relationships used in this study consider only granular propellant. Once the manufacturing process for stick propellant has been established in country and stabilized (12-18 months), the stick propellant should be about 50 percent more expensive than the average M30 granular propellant. Current estimated unit costs for these rounds are:

	MP	TP-MP
Total round	$185.436	$100.615
Propellant	25.732	21.784

Increasing the total round unit cost by adding 50 percent more cost for propellant changes the above costs as follows:

	MP	TP-MP
Total round	$198.302	$111.507
% Increase	6.9%	10.8%
Total program increase	$ 12.1 million	$111.7 million

d. Use of DU Penetrators for the 120mm Options - The use of tungsten alloy penetrators in the APFSDS round is significantly more costly than DU penetrators. Thus, the extra cost of the two 120mm options may be falsely attributed to bore size change when compared to the cost of the 105mm DU APFSDS round. This is shown below:

	UK 120mm	GE 120mm
Tungsten	$400.610	$412.393
DU	334.479	342.199
% Difference	19.8%	20.5%

Using the DU penetrator rather than tungsten penetrator would produce lower program costs as follows:

For the German round	$85.2 million decrease
For the British round	$80.3 million decrease

Use of a 120mm DU penetrator reduces the cost advantage attributable to the 105mm option as follows:

120MM
Increased Cost From 105mm DU

	Tungsten	DU
UK	51%	26%
GE	56%	29%

III. SUPPLEMENTAL DATA

Supplemental data pertaining to production schedules and requirements, independent variables, and average unit costs follow in Tables 7 through 26 inclusive.

NOTE: A component cost breakout for the US APFSDS round will be provided later in a classified annex.

PRODUCTION SCHEDULES AND REQUIREMENTS

TABLE 7

AMMUNITION PRODUCTION SCHEDULES

YEAR END CUMULATIVE TOTALS IN THOUSANDS

	MP	APFSDS	WP/SMOKE	APERS	TPFSDS	MP-TP
US Only						
1983	189.0	204.6	13.0	3.0	284.0	503.0
1985	567.0	613.8	39.0	9.0	852.0	1509.0
1994	945.0	1023.0	226.0	15.0	3408.0	6036.0
2007	-----	-----	525.0	-----	7100.0	12575.0
US Phaseout						
1983	90.0	77.6	8.0	-----	271.0	480.0
1985	270.0	232.8	24.0	-----	665.0	1178.0
1994	450.0	388.0	70.0	-----	1307.0	2315.0
2007	-----	-----	-----	-----	-----	-----
UK/GE						
1983	98.0	127.0	-----	-----	13.0	23.0
1985	294.0	381.0	46.0	10.0	186.0	330.0
1994	943.0	1214.0	253.0	36.0	2097.0	3715.0
2007	-----	-----	552.0	-----	5789.0	10254.0

TABLE 8

COMPONENT REQUIREMENTS

YEAR END CUMULATIVE TOTALS IN THOUSANDS

	UK/GE	US ONLY	US PHASEOUT
LAP/Projectiles			
MP			
1983	98.0	189.0	90.0
1985	294.0	567.0	270.0
1994	943.0	945.0	450.0
2007	-----	-----	-----
APFSDS			
1983	127.0	204.6	77.6
1985	381.0	613.8	232.8
1994	1214.0	1023.0	388.0
2007	-----	-----	-----
WP/SMOKE			
1983	-----	13.0	8.0
1985	46.0	39.0	24.0
1994	253.0	226.0	70.0
2007	552.0	525.0	-----
APERS			
1983	-----	3.0	-----
1985	10.0	9.0	-----
1994	36.0	15.0	-----
2007	-----	------	-----
TPFSDS			
1983	13.0	284.0	271.0
1985	186.0	852.0	665.0
1994	2097.0	3408.0	1307.0
2007	5789.0	7100.0	-----
MP-TP			
1983	23.0	503.0	480.0
1985	330.0	1509.0	1178.0
1994	3715.0	6036.0	2315.0
2007	10254.0	12575.0	-----

TABLE 8 Cont'd

	UK/GE	US ONLY	US PHASEOUT
Cases/Electric Primers			
1983	261.0	1196.6	926.6
1985	1247.0	3589.8	2369.8
1994	8258.0	11653.0	4530.0
2007	18788.0	22183.0	-----
Fuzes			
PIBD (MP)			
1983	98.0	189.0	90.0
1985	294.0	567.0	270.0
1994	943.0	945.0	450.0
2007	-----	-----	-----
PD (WP/SMOKE)			
1983	-----	13.0	8.0
1985	46.0	39.0	24.0
1994	253.0	226.0	70.0
2007	552.0	525.0	-----
MT (APERS)			
1983	-----	3.0	-----
1985	10.0	9.0	-----
1994	36.0	15.0	-----
2007	-----	-----	-----

INDEPENDENT VARIABLES

TABLE 9

TANK AMMUNITION STUDY
COUNTRY UK

BORE SIZE 120MM

TYPE	STAB	IN-BORE WT (lbs)	IN-FLIGHT WT (lbs)	PENETRATOR MAT'L	CASE MAT'L	MUZZLE VELOCITY ft/sec	MASS[1]	MUZZLE[2] MOMENTUM	KINETIC[3] ENERGY	
MP	Fin	32.0	32.0	Tu	COMBUSTIBLE	3845	.9938	3821.12	7,346,099	
MP-TP	Fin	25.68	25.68	Tu	COMBUSTIBLE	3800	.7975	3030.56	5,758,062	
WP/SMOKE	Spin	32.5	32.5	Tu	COMBUSTIBLE	2400	1.0093	2422.36	2,906,832	
APERS	Spin	39.65	39.65	Tu	COMBUSTIBLE	2700	1.2314	3324.69	4,488,331	
APFSDS	Fin	17.5	9.8	Tu	COMBUSTIBLE	5230	.5435	2842.39	7,432,853	In Bore
							.3043	1591.74	4,162,398	In Flight
TPFSDS	Fin	13.52	7.54	Tu	COMBUSTIBLE	5000	.4199	2099.38	5,248,447	In Bore
							.2342	1170.81	2,927,019	In Flight

All rounds have electric primers.

1/ Mass is that value determined by dividing projectile weight by the force of gravity, which is 32.2 feet per second per second.

2/ Muzzle Momentum is a product of projectile mass and muzzle velocity.

3/ Kinetic Energy is the product of muzzle velocity squared and 1/2 the mass.

TABLE 10

TANK AMMUNITION STUDY
COUNTRY GE

BORE SIZE 120MM

TYPE	STAB	IN-BORE WT (lbs)	IN-FLIGHT WT (lbs)	PENETRATOR MAT'L	CASE MAT'L	MUZZLE VELOCITY ft/sec	MASS	MUZZLE MOMENTUM	KINETIC ENERGY	
MP	Fin	28.64	28.64	Tu	COMBUSTIBLE	3740	.8894	3326.51	6,220,572	
MP-TP	Fin	22.16	22.16	Tu	COMBUSTIBLE	3800	.6882	2615.16	4,968,795	
WP/SMOKE *	Fin	32.5	32.5	Tu	COMBUSTIBLE	2400	1.0093	2422.36	2,906,832	
APERS *	Fin	39.65	39.65	Tu	COMBUSTIBLE	2700	1.2314	3324.69	4,488,331	
APFSDS	Fin	15.9	10.4	Tu	COMBUSTIBLE	5420	.4938	2676.34	7,252,869	In Bore
							.3230	1750.56	4,744,015	In Flight
TPFSDS *	Fin	13.52	7.54	Tu	COMBUSTIBLE	5000	.4199	2099.38	5,248,447	In Bore
							.2342	1170.81	2,927,019	In Flight

All rounds have electric primers.

* Physical characteristics same as UK 120MM round.

TABLE 11

TANK AMMUNITION STUDY
COUNTRY US

BORE SIZE 105MM

TYPE	STAB	IN-BORE WT (lbs)	IN-FLIGHT WT (lbs)	PENETRATOR MAT'L	CASE MAT'L	MUZZLE VELOCITY ft/sec	MASS	MUZZLE MOMENTUM	KINETIC ENERGY	
MP	Fin	24.8	24.8	DU	STEEL	3850	.7702	2965.22	5,708,043	
MP-TP	Fin	22.35	22.35	DU	STEEL	3850	.6941	2672.28	5,144,144	
WP/SMOKE	Spin	25.0	25.0	DU	STEEL	2400	.7764	1863.35	2,236,025	
APERS	Spin	30.5	30.5	DU	STEEL	2700	.9472	2557.45	3,452,562	
APFSDS	- See Classified Annex -									
TPFSDS	Fin	10.9	5.8	DU	STEEL	5050	.3385	1709.47	4,316,417	In Bore
							.1801	909.63	2,296,809	In Flight

All rounds have electric primers.

AVERAGE UNIT COSTS

COUNTRY
UK

TABLE 12

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1983

	MP	APFSDS	WP/SMOKE *	APERS *	TPFSDS	MP-TP
LAP	$ 36.70	$ 14.70	----	-----	$ 14.70	$ 10.40
Proj Mpts.	61.60	311.40	----	-----	130.10	52.60
Fill	2.10	N/A	----	-----	N/A	N/A
Case	17.30	17.30	----	-----	17.30	17.30
Propellant	29.10	29.40	----	-----	22.70	24.30
Primer	17.20	17.20	----	-----	17.20	17.20
Fuze	7.90	N/A	----	-----	N/A	N/A
Transportation	5.30	2.90	----	-----	2.30	4.30
Other Expl. Elements	36.00	19.10	----	-----	17.20	17.20
Total U. C. FY 77 $	$213.20	$412.00	----	-----	$221.50	$143.30

* No production scheduled for 1983.

Costs rounded to nearest ten cents.

COUNTRY
UK

TABLE 13

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1985

	MP	APFSDS	WP/SMOKE	APERS	TPFSDS	MP-TP
LAP	$ 36.70	$ 14.70	$ 41.60	$ 52.70	$ 14.70	$ 10.40
Proj Mpts.	54.50	311.40	40.20	303.60	130.10	39.10
Fill	2.10	N/A	N/A	N/A	N/A	N/A
Case	17.30	17.30	17.30	17.30	17.30	17.30
Propellant	29.10	29.40	14.60	20.20	22.70	24.30
Primer	10.50	10.50	10.50	10.50	10.50	10.50
Fuze	6.80	N/A	11.90	178.00	N/A	N/A
Transportation	5.30	2.90	5.40	6.60	2.30	4.30
Other Expl. Elements	36.00	19.10	25.40	7.70	17.20	17.20
Total U. C. FY 77 $	$198.30	$405.30	$166.90	$596.60	$214.80	$123.10

Costs rounded to nearest ten cents.

COUNTRY
UK

TABLE 14

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1994

	MP	APFSDS	WP/SMOKE	APERS	TPFSDS	MP-TP
LAP	$ 36.70	$ 14.70	$ 41.60	$ 52.70	$ 14.70	$ 10.40
Proj Mpts.	47.90	311.40	33.30	263.40	130.10	29.90
Fill	2.10	N/A	N/A	N/A	N/A	N/A
Case	17.30	17.30	17.30	17.30	17.30	17.30
Propellant	29.10	29.40	14.60	20.20	22.70	24.30
Primer	5.80	5.80	5.80	5.80	5.80	5.80
Fuze	5.80	N/A	9.50	149.80	N/A	N/A
Transportation	5.30	2.90	5.40	6.60	2.30	4.30
Other Expl. Elements	36.00	19.10	25.40	7.70	17.20	17.20
Total U. C. FY 77 $	$186.00	$400.60	$152.90	$523.50	$210.10	$109.20

Costs rounded to nearest ten cents.

COUNTRY
UK

TABLE 15

COMPONENT AVERAGE UNIT COSTS THROUGH FY 2007

	MP *	APFSDS *	WP/SMOKE	APERS *	TPFSDS	MP-TP
LAP	----	----	$ 41.60	-----	$ 14.70	$ 10.40
Proj Mpts.	----	----	30.50	-----	130.10	26.70
Fill	----	----	N/A	-----	N/A	N/A
Case	----	----	17.30	-----	17.30	17.30
Propellant	----	----	14.60	-----	22.70	24.30
Primer	----	----	4.50	-----	4.50	4.50
Fuze	----	----	8.50	-----	N/A	N/A
Transportation	----	----	5.40	-----	2.30	4.30
Other Expl. Elements	----	----	25.40	-----	17.20	17.20
Total U. C. FY 77 $	$186.00	$400.60	$147.80	$523.50	$208.80	$104.70

* No production scheduled after 1994.

Costs rounded to nearest ten cents.

COUNTRY
GE

TABLE 16

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1983

	MP	APFSDS	WP/SMOKE *	APERS *	TPFSDS	MP-TP
LAP	$ 36.70	$ 13.40	----	-----	$ 13.40	$ 9.50
Proj Mpts.	61.60	325.30	----	-----	135.30	52.60
Fill	2.10	N/A	----	-----	N/A	N/A
Case	17.30	17.30	----	-----	17.30	17.30
Propellant	25.70	28.80	----	-----	22.70	21.80
Primer	17.20	17.20	----	-----	17.20	17.20
Fuze	12.30	N/A	----	-----	N/A	N/A
Transportation	4.80	2.60	----	-----	2.30	3.70
Other Expl. Elements	36.00	19.10	----	-----	17.20	17.20
Total U. C. FY 77 $	$213.70	$423.70	----	-----	$225.40	$139.30

* No production scheduled for 1983.

Costs rounded to nearest ten cents.

COUNTRY
GE

TABLE 17

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1985

	MP	APFSDS	WP/SMOKE	APERS	TPFSDS	MP-TP
LAP	$ 36.70	$ 13.40	$ 41.60	$ 52.70	$ 13.40	$ 9.50
Proj Mpts.	54.50	325.30	40.20	303.60	135.30	39.10
Fill	2.10	N/A	N/A	N/A	N/A	N/A
Case	17.30	17.30	17.30	17.30	17.30	17.30
Propellant	25.70	28.80	14.60	20.20	22.70	21.80
Primer	10.50	10.50	10.50	10.50	10.50	10.50
Fuze	10.60	N/A	11.90	178.00	N/A	N/A
Transportation	4.80	2.60	5.40	6.60	2.30	3.70
Other Expl. Elements	36.00	19.10	25.40	7.70	17.20	17.20
Total U. C. FY 77 $	$198.20	$417.00	$166.90	$596.60	$218.70	$119.10

Costs rounded to nearest ten cents.

TABLE 18

COUNTRY
GE

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1994

	MP	APFSDS	WP/SMOKE	APERS	TPFSDS	MP-TP
LAP	$ 36.70	$ 13.40	$ 41.60	$ 52.70	$ 13.40	$ 9.50
Proj Mpts.	47.90	325.30	33.30	263.40	135.30	29.90
Fill	2.10	N/A	N/A	N/A	N/A	N/A
Case	17.30	17.30	17.30	17.30	17.30	17.30
Propellant	25.70	28.80	14.60	20.20	22.70	21.80
Primer	5.80	5.80	5.80	5.80	5.80	5.80
Fuze	9.10	N/A	9.50	149.80	N/A	N/A
Transportation	4.80	2.60	5.40	6.60	2.30	3.70
Other Expl. Elements	36.00	19.10	25.40	7.70	17.20	17.20
Total U. C. FY 77 $	$185.40	$412.30	$152.90	$523.50	$214.00	$105.20

Costs rounded to nearest ten cents.

TABLE 19

COUNTRY
GE

COMPONENT AVERAGE UNIT COSTS THROUGH FY 2007

	MP *	APFSDS *	WP/SMOKE	APERS *	TPFSDS	MP-TP
LAP	----	----	$ 41.60	-----	$ 13.40	$ 9.50
Proj Mpts.	----	----	30.50	-----	135.30	26.70
Fill	----	----	N/A	-----	N/A	N/A
Case	----	----	17.30	-----	17.30	17.30
Propellant	----	----	14.60	-----	22.70	21.80
Primer	----	----	4.50	-----	4.50	4.50
Fuze	----	----	8.50	-----	N/A	N/A
Transportation	----	----	5.40	-----	2.30	3.70
Other Expl. Elements	----	----	25.40	-----	17.20	17.20
Total U. C. FY 77 $	$185.40	$412.30	$147.80	$523.50	$212.70	$100.70

* No production scheduled after 1994.

Costs rounded to nearest ten cents.

TABLE 20

COUNTRY
US ONLY

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1983

	MP	APFSDS *	WP/SMOKE *	APERS *	TPFSDS	MP-TP
LAP	$ 27.70	----	----	-----	$ 10.80	$ 8.90
Proj Mpts.	37.40	----	----	-----	109.80	28.10
Fill	1.50	----	----	-----	N/A	N/A
Case	13.80	----	----	-----	13.80	13.80
Propellant	19.10	----	----	-----	15.50	17.70
Primer	6.20	----	----	-----	6.20	6.20
Fuze	4.30	----	----	-----	N/A	N/A
Transportation	4.10	----	----	-----	1.80	3.70
Other Expl. Elements	30.20	----	----	-----	11.40	11.40
Total U. C. FY 77 $	$144.30	$269.50	$124.90	$369.80	$169.30	$89.80

* WP/SMOKE and APERS total costs represent latest procurement costs:
APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

TABLE 21

COUNTRY
US ONLY

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1985

	MP	APFSDS *	WP/SMOKE *	APERS *	TPFSDS	MP-TP
LAP	$ 27.70	----	----	-----	$ 10.80	$ 8.90
Proj Mpts.	33.10	----	----	-----	109.80	24.90
Fill	1.50	----	----	-----	N/A	N/A
Case	12.90	----	----	-----	12.90	12.90
Propellant	19.10	----	----	-----	15.50	17.70
Primer	4.80	----	----	-----	4.80	4.80
Fuze	3.70	----	----	-----	N/A	N/A
Transportation	4.10	----	----	-----	1.80	3.70
Other Expl. Elements	30.20	----	----	-----	11.40	11.40
Total U. C. FY 77 $	$137.10	$267.20	$124.90	$369.80	$167.00	$84.30

* WP/SMOKE and APERS total costs represent latest procurement costs; APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

COUNTRY
US ONLY

TABLE 22

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1994

	MP	APFSDS *	WP/SMOKE *	APERS *	TPFSDS	MP-TP
LAP	$ 27.70	----	----	-----	$ 10.80	$ 8.90
Proj Mpts.	31.30	----	----	-----	109.80	21.30
Fill	1.50	----	----	-----	N/A	N/A
Case	11.80	----	----	-----	11.80	11.80
Propellant	19.10	----	----	-----	15.50	17.70
Primer	3.50	----	----	-----	3.50	3.50
Fuze	3.50	----	----	-----	N/A	N/A
Transportation	4.10	----	----	-----	1.80	3.70
Other Expl. Elements	30.20	----	----	-----	11.40	11.40
Total U. C. FY 77 $	$132.70	$264.80	$124.90	$369.80	$164.60	$78.30

* WP/SMOKE and APERS total costs represent latest procurement costs; APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

TABLE 23

COUNTRY
US ONLY

COMPONENT AVERAGE UNIT COSTS THROUGH FY 2007

	MP *	APFSDS *	WP/SMOKE *	APERS *	TPFSDS	MP-TP
LAP	----	----	----	-----	$ 10.80	$ 8.90
Proj Mpts.	----	----	----	-----	109.80	19.70
Fill	----	----	----	-----	N/A	N/A
Case	----	----	----	-----	11.20	11.20
Propellant	----	----	----	-----	15.50	17.70
Primer	----	----	----	-----	2.90	2.90
Fuze	----	----	----	-----	N/A	N/A
Transportation	----	----	----	-----	1.80	3.70
Other Expl. Elements	----	----	----	-----	11.40	11.40
Total U. C. FY 77 $	$132.70	$264.80	$124.90	$369.80	$163.40	$75.50

* WP/SMOKE and APERS total costs represent latest procurement costs;
APFSDS component breakout provided in classified annex;
No production of MP, APFSDS, and APERS rounds scheduled after 1994.

Costs rounded to nearest ten cents.

TABLE 24

COUNTRY
US PHASEOUT

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1983

	MP	APFSDS *	WP/SMOKE *	APERS *	TPFSDS	MP-TP
LAP	$ 27.70	----	----	-----	$ 10.80	$ 8.90
Proj Mpts.	40.60	----	----	-----	109.80	28.20
Fill	1.50	----	----	-----	N/A	N/A
Case	14.00	----	----	-----	14.00	14.00
Propellant	19.10	----	----	-----	15.50	17.70
Primer	6.50	----	----	-----	6.50	6.50
Fuze	4.70	----	----	-----	N/A	N/A
Transportation	4.10	----	----	-----	1.80	3.70
Other Expl. Elements	30.20	----	----	-----	11.40	11.40
Total U. C. FY 77 $	$148.40	$270.00	$124.90	-----	$169.80	$90.40

* WP/SMOKE and APERS total costs represent latest procurement costs; APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

TABLE 25

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1985

COUNTRY US PHASEOUT	MP	APFSDS *	WP/SMOKE *	APERS *	TPFSDS	MP-TP
LAP	$ 27.70	----	----	-----	$ 10.80	$ 8.90
Proj Mpts.	36.00	----	----	-----	109.80	25.60
Fill	1.50	----	----	-----	N/A	N/A
Case	13.30	----	----	-----	13.30	13.30
Propellant	19.10	----	----	-----	15.50	17.70
Primer	5.30	----	----	-----	5.30	5.30
Fuze	4.10	----	----	-----	N/A	N/A
Transportation	4.10	----	----	-----	1.80	3.70
Other Expl. Elements	30.20	----	----	-----	11.40	11.40
Total U. C. FY 77 $	$141.30	$268.10	$124.90	-----	$167.90	$85.90

* WP/SMOKE and APERS total costs represent latest procurement costs; APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

COUNTRY
US PHASEOUT

TABLE 26

COMPONENT AVERAGE UNIT COSTS THROUGH FY 1994

	MP	APFSDS *	WP/SMOKE *	APERS *	TPFSDS	MP-TP
LAP	$ 27.70	----	----	-----	$ 10.80	$ 8.90
Proj Mpts.	34.00	----	----	-----	109.80	23.70
Fill	1.50	----	----	-----	N/A	N/A
Case	12.70	----	----	-----	12.70	12.70
Propellant	19.10	----	----	-----	15.50	17.70
Primer	4.50	----	----	-----	4.50	4.50
Fuze	3.80	----	----	-----	N/A	N/A
Transportation	4.10	----	----	-----	1.80	3.70
Other Expl. Elements	30.20	----	----	-----	11.40	11.40
Total U. C. FY 77 $	$137.60	$266.70	$124.90	-----	$166.50	$82.60

* WP/SMOKE and APERS total costs represent latest procurement costs; APFSDS component breakout provided in classified annex.

Costs rounded to nearest ten cents.

METHODOLOGY

IV. Methodology

A. Average Unit Cost for Gun Manufacture

1. Cost estimating relationship.

a. The data base utilized for this estimate is included in reference 3. In reference 3, estimating relationships correlating applied momentum to cost and cannon weight to cost are used independently. Neither of these relationships give satisfactory results for this estimate because the UK and GE cannons exchange rankings of momentum and weight. The reference 3 data base was subjected to multilinear regression with both weight and momentum as independent variables to solve this problem. The results are:

$W = A + BX + CY$ Where:

W = Unit cost in FY 72 $ (excluding Product Assurance and Engineering Support)
X = Weight in pounds of the cannon breech assembly (less muzzle brake and bore evacuation)
Y = Momentum in lb/secs for highest momentum generated
A = 4113.83
B = 1.2067
C = 0.4134

Statistics:

Coefficients of Determination

Multiple = .976

Partial
$WX \cdot Y = .2911$
$WY \cdot X = .1048$
$XY = .976$

Standard error of the estimate = 1675
N = 8

b. Independent Variables: The weights of the cannon and breech assemblies for the UK and GE options are taken from reference 8 as 3912 and 4282 pounds respectively. The momentums in lbs/secs are calculated at 3821.12 for UK and 3326.51 for GE on the basis of the round variables provided in Section III, paragraph B of this report.

2. Inflation.

Historical inflation for general items of ordnance has not moved as fast as that for cannon manufacture. Therefore, it is necessary to construct a special inflation rate to escalate from FY 72 to FY 76. The most reasonable proxy for actual price movement is the change in Wholesale Price Index (WPI) Code 1015-1053, Closed Die Forging Alloy Steel. The amount of change through the period FY 72 to FY 76 has been 75 percent comparing reference 10 and reference 11. An additional 10.07 percent is forecast between FY 76 and FY 77 (reference 5). The total multiplier then becomes 1.9262 (1.75 X 1.1007) to be applied on the output of the gun cost estimating relationships described above.

3. Adjustment for Smoothbore Gun.

The 120mm UK gun is a rifled gun similar to the items in the data base. The 120mm GE gun is of a smoothbore configuration, and its costs require adjustment. Reference 7 places the cost of rifling at 4.3 percent of the 120mm tube manufacturing cost and the cost of other processes contributing to the smoothbore configuration (including chrome plate, grinding and honing) at 11.6 percent of tube cost. Since the tube is 1/3 the cost of the total cannon breech assembly cost, the cost of rifling can be extracted from the CER by multiplying by .9857 -

$$\frac{1}{3} \text{ X } .043 = .0143, \; 1 - .0143 = .9857.$$

The smooth bore cost can be added to the cost of cannon, less rifling through the multiplier 1.0402 -

$$\frac{1}{3} \text{ X } .116 = .0387, \; 1 - .0387 = .9613, \; \frac{1}{.9613} = 1.0402.$$

Thus, the one step multiplier to convert output of the CER to the smoothbore configuration is the product of .9857 and 1.0402, or 1.0253.

4. Adjustment for Bore Evacuation System.

Reference 7 provides that the UK bore evacuator, and the GE evacuator are 2.5 percent and 0.7 percent of the total costs respectively -

$$\frac{1}{(1-.025)} = 1.0256, \; \frac{1}{(1-.007)} = 1.007.$$

5. Costs for Product Assurance and Engineering Support.

These costs were extracted and used as is from the Watervliet Arsenal engineering cost estimate. The GE cost is $1,228 and the UK cost is $1,020.

B. AMMUNITION MANUFACTURING COSTS

1. General Approach

a. The basic methodology for developing the ammunition portion of the estimate was derived from reference 1. The ammunition was broken out into the individual components that would be procured. These elements were then costed by applying Cost Estimating Relationships (CER's) developed in reference 1. Section IV, paragraph B2, gives a complete list of the CER's that were taken from the study. It also indicates the pages upon which the detailed description of the CER's and their associated statistics can be found.

b. Since the ammunition study (reference 1) did not develop LAP and projectile costs for APERS, TPDS, and WP rounds, complexity factors were developed for this study based upon the relationships between weighted average costs of HEAT LAP's and projectiles compared to buys of APERS and WP rounds. These complexity factors are also listed in Section IV, paragraph B2. A detailed description of their development is given in Section IV, paragraph B3. It should be noted that it was decided that the costs of LAP for TPDS and APDS rounds would be essentially identical.

c. A final requirement for developing complete round costs involved the necessity of estimating costs for certain explosive elements for which CER's are not contained within reference 1. Failure to include these costs would have resulted in a significant underpricing of the ammunition. For this reason, the current ammunition component price list (reference 9) was utilized to extract current costs for explosive elements from US 105mm rounds in production. The M456A1 (HEAT), the M392A2 (APDS), the M416 (WP), the M494 (APERS), the M742 (TPDS), and M490 (TP) were the sources for this data. It was assumed that these costs would remain relatively constant for the new family of US tank rounds. In order to project costs for the 120mm, the HE Fill CER (LnZ=14.3343 + 3.1763 Ln bore size) was used to calculate the percentage difference between 105mm and 120mm rounds. A factor of 1.51 (rounded) was applied to the US rounds to estimate the corresponding German and English rounds. In addition, it should be noted that the US HEAT round Other Explosive Elements category contains a Full Frontal Area Impact Switch with a current cost of $18.834. It was assumed that the US would want this technology to be incorporated in the corresponding 120mm rounds, so this cost was also applied.

d. After all of the equations in Section IV, paragraph B2, had been calculated, utilizing the variables and production schedules provided in Section III (A and B), the results were converted to FY 77 dollars by application of inflation factors in references 4 and 5. All results were then placed in the matrix provided on the following page (Figure 1). This matrix became the basis for the cost tables in Section III-C of the study. It includes the identification number of the appropriate equation for each component, and it also identifies the requirement for throughput data provided in Section IV, paragraph B4.

AMMUNITION COST DEVELOPMENT MATRIX

	MP	APFSDS	WP/SMOKE	APERS	TPFSDS	MP-TP
LAP	1	4	2	3	4	5
Proj. Mpts.	6	9	7	8	11	10
Fill	12	N/A	N/A	N/A	N/A	N/A
Case						
Steel	13	13	13	13	13	13
Combustible	14	14	14	14	14	14
Propellant	15	15	15	15	15	15
Primer	16	16	16	16	16	16
Fuze	17	N/A	18	19	N/A	N/A
Transportation	20	20	20	20	20	20
Other Explosive Elements	- - - - - - - - - - - - - - - Throughput - - - - - - - - - - - - - - -					

Numbers in matrix are keyed to Section IV, paragraph B2.

FIGURE 1

2. COST ESTIMATING RELATIONSHIPS

a. LAP Costs

(1) Equation No. 1 - MP (HEAT)

LnZ = -6.8639 + 2.1143 LnX
Where: Z = Estimated unit cost in FY 74 dollars
X = Bore size in millimeters

Ref. #1, pp 112-113.

(2) Equation No. 2 - WP/SMOKE

MP LAP unit cost (FY 74 $) from Equation No. 1 times 1.1388 complexity factor. See Section IV, Paragraph B(3) of this study.

(3) Equation No. 3 - APERS

MP LAP unit cost (FY 74 $) from Equation No. 1 times 1.4334 complexity factor. See Section IV, Paragraph B(3) of this study.

(4) Equation No. 4 - APFSDS/TPFSDS (AP)

LnZ = 2.9272 - 0.000002941 X + 0.9583 LnY
Where: Z = Estimated unit cost in FY 74 dollars
X = Average annual production rate in thousands
Y = Projectile mass

Ref. #1, pp 113-114.

(5) Equation No. 5 - MP-TP (TP)

LnZ = 4.1000 - 0.3247 LnX + 0.6453 LnY
Where: Z = Estimated unit cost in FY 74 dollars
X = Average annual production rate in thousands
Y = Projectile mass

Ref. #1, pp 114-115.

b. Projectile Costs

(1) Equation No. 6 - MP (HEAT)

Theoretical first unit cost (FY 74 $) of $90.61 for 105mm;

Theoretical first unit cost (FY 74 $) of $138.65 for 120mm;

92.6% composite learning rate applies.

Ref. #1, p 117.

(2) Equation No. 7 - WP/SMOKE

HEAT theoretical first unit cost (FY 74 $) from Equation No. 6 times .6007 complexity factor.

92.6% composite learning rate applies.

See Section IV, Paragraph B(3) of this study.

(3) Equation No. 8 - APERS

HEAT theoretical first unit cost (FY 74 $) from Equation No. 6 times 3.8289 complexity factor.

92.6% composite learning rate applies.

See Section IV, Paragraph B(3) of this study.

(4) Equation No. 9 - APFSDS (APDS)

$$Z = \text{Antiln}\ (3.1417 + 0.009529X) + (116.91 + 52.80T \left(\frac{Y}{0.2640}\right) + 16.73 \left(\frac{Y}{0.2640}\right)^{0.6667}$$

Where: Z = Estimated unit cost in FY 76 dollars
X = Full bore size in millimeters
Y = In-flight projectile mass
T = Material type conditional code
= 0 if depleted uranium core
= 1 if tungsten alloy core

Ref. #1, pp 123-123.

(5) Equation No. 10 - APFSDS

APFSDS estimated unit cost (FY 76 $) from Equation No. 9 with depleted uranium core times .5303 complexity factor.

See Section IV, Paragraph B(3) of this study.

(6) Equation No. 11 - MP-TP (TP)

$$\text{Ln}Z = -5.5868 + 2.1305\ \text{Ln}X$$

Where: Z = Estimated theoretical first unit cost in FY 74 dollars
X = Bore size in millimeters

Ref. #1, p 124.

c. Explosive Fill

Equation No. 12 - MP (HEAT)

LnZ = -12.3829 + 2.6706 LnX
Where: Z = Estimated unit cost in FY 74 dollars
X = Bore size in millimeters

Ref. #1, p 126.

d. Cases

(1) Equation No. 13 - Steel

LnZ = 1.0625 + 0.02063 X + 0.2022 Y
Where: Z = Estimated theoretical first unit cost in FY 74 dollars
X = Bore size in millimeters
Y = Projectile mass

94.3% composite learning rate applies.

(2) Equation No. 14 - Combustible

LnZ = 1.2865 + 0.01015 X
Where: Z = Estimated unit cost in FY 74 dollars
X = Bore size in millimeters

Ref. #1, p 134.

e. Propellants

Equation No. 15 - Propellants

LnZ = -10.5840 + 0.01571 X + 0.7416 LnY
Where: Z = Estimated unit cost in FY 74 dollars
X = Bore size in millimeters
y = Kinetic energy

Ref. #1, pp 135-137.

f. Primers

Equation No. 16 - Electric

LnZ = -14.1220 + 4.0538 LnX - 0.9031 LnY
Where: Z = Estimated theoretical first unit cost in FY 74 dollars
X = Round application bore size in millimeters
Y = Round application projectile mass

80.3% composite learning rate applies.

Ref #1, p 139.

g. Fuzes

(1) Equation No. 17 - MP (PIBD)

LnZ = -52.3486 + 11.5814 LnX - 4.0205 LnY
Where: Z = Estimated theoretical first unit cost in FY 74 dollars
X = Round application bore size in millimeters
Y = Round application projectile mass

91.1% composite learning rate applies.

Ref. #1, pp 143-144.

(2) Equation No. 18 - WP/SMOKE (PD)

LnZ = 14.0768 - 2.2258 LnX + 1.0590 LnY
Where: Z = Estimated theoretical first unit cost in FY 74 dollars
X = Round application bore size in millimeters
Y = Round application projectile mass

91.1% composite learning rate applies.

Ref. #1, pp 141-142.

(3) Equation No. 19 - APERS (MT)

Theoretical first unit cost (FY 74 $) of $376.35

91.1% composite learning rate applies.

Ref. #1, p 144.

h. Transportation

Equation No. 20 - Transportation

LnZ = 1.5214 + 1.0029 LnX
Where: Z = Estimated unit cost in FY 75 dollars
X = Projectile mass

Ref. #1, pp 149-150.

3. COMPLEXITY FACTORS

a. This study draws heavily upon references 1 and 2. It should be noted that both references 1 and 2 refer to generic titles for the various round families. Hence, the MP and MP-TP categories, as referred to in this report, are denoted in references 1 and 2 as HEAT and TP. Correspondingly, WP/SMOKE rounds are referred to as WP. The APFSDS and TPFSDS rounds are respectively called APDS and TPDS in references 1 and 2. In order to facilitate tracking with the basic references, this methodology section utilizes the generic descriptions found in references 1 and 2. Reference 2 contains unit cost-quantity data for LAP costs and projectile metal parts production for selected ammunition items between FY 57 and FY 75. All costs pertaining to HEAT, APERS, WP, TPDS, and APDS rounds were extracted. In addition, a file search was conducted in DRSAR-PDC records pertaining to LAP and projectile metal parts costs. Additional information for FY 76 and FY 77, and for several earlier buys not listed in the annex, was compiled. All of this data was then converted into unit costs in FY 76 dollars. In order to facilitate comparison of the rounds under study, the data were then purified by the deletion of obviously inconsistent cost-quantity information (i.e., an FY 72 buy of M456A1 projectiles was deleted because it had an average unit cost of $436.72 in FY 76 dollars, while the average unit cost of all other orders was $44.34). A weighted average unit cost for each round in the data base was then developed so that individual rounds could be compared readily (see Charts 1 and 2).

b. These weighted averages were used as the basis for the developing of complexity/conversion factors. Reference 2 contains a CER for estimating the LAP and actual costs for the 105mm and 120mm HEAT projectile parts. It was decided to use an analogy process, comparing the HEAT with the WP and APERS rounds, to develop factors which could be used to convert the projected costs for a HEAT round to projected APERS and WP costs. Similarly, a conversion factor was developed for the CER for APDS rounds projectile metal parts by comparing the APDS metal parts cost to the TPDS metal parts cost.

Complexity Factor 1 - A complexity factor of 1.1338 was developed to convert output from the HEAT LAP cost CER to that of a WP round. This was done by comparing the average cost of the only WP tank round on which data was available, the 105mm M416, to the normalized weighted average cost of HEAT rounds in the data base. Two of the rounds on which data was available, the 76mm M496 and the 90mm M431A2, are obsolete rounds that were produced in only limited quantities. They were removed from the data base in order not to skew the results. This left the following rounds in the data base (see Table 27).

CHART 1

LAP COSTS FY 76 $

HEAT	APERS	WP	TPDS	APDS
$15.157 M344A1 w/o Fuze 106mm	$22.549 M580-90mm	$22.504 M416-105mm	$10.736 M724-105mm	$11.760 M391A1/A2-105mm
$16.415 M371E1-90mm	$23.550 M581-106mm			
$16.826 M456-105mm	$33.626 M494-105mm			
$18.197 M344A1 w Fuze 106mm				
$31.969 M496-76mm				
$36.092 M431A2-90mm				
$65.525 M409-152mm				

CHART 2

PROJECTILE METAL PARTS COSTS FY 76 $

HEAT	APERS	WP	TPDS	APDS
$21.231 M371A1-90mm	$113.807 M580-90mm	$24.461 M416-105mm	$76.713 M724A1-105mm	$144.652 M392A1/A2-105mm
$36.548 M344A1-106mm	$165.369 M494-105mm			
$44.337 M456A1-105mm	$170.568 M581-106mm			
$51.574 M496-76mm				
$71.848 M431-90mm				
$147.086 M409-152mm				

TABLE 27

Bore Size	Nomenclature	Wtd Avg Price	Quantity	Normalized Wtd Avg Price
90mm	M371E1	$16.415	619,432	$22.735
105mm	M456	16.826	975,095	16.826
106mm	M344A1 w/o Fuze	15.157	61,515	14.860
106mm	M344A1 w Fuze	18.197	801,366	17.840
152mm	M409	65.525	303,893	29.975

In order to normalize this data in terms of 105mm costs, it was necessary to utilize the HEAT LAP CER = Ln Est. U.C. in FY 74 $ = -6.8639 + (2.1143 X Ln Bore Size). Since the independent variable in this equation is bore size, it was felt that the data could be normalized by finding the CER projected differences for the bore sizes involved. These results were obtained:

TABLE 28

Bore Size	Est U.C.	Conversion Factor Based on 105mm
90mm	$14.155	1.385
105mm	19.609	1.000
106mm	20.006	.980
152mm	42.866	.457

By applying the conversion factors developed in this manner, normalized weighted average prices were obtained (see Table 27). The weighted average of these normalized prices is $19.849. This compares to the average cost of $22.504 for the M416 WP round (Chart 1). The latter figure is 1.1338 times the normalized average HEAT round LAP cost.

Complexity Factor 2 - A complexity factor of 1.4334 was developed to convert output from the HEAT LAP cost CER to that of an APERS round. The same methodology was followed as for complexity factor 1. The normalized average cost of $19.849 for the HEAT round was compared to the normalized weighted average cost of $28.451 for the APERS round. Table 29 summarizes the coversion process.

TABLE 29

Bore Size	Nomenclature	Wtd Avg Price	Quantity	Normalized Wtd Avg Price
90mm	M580	$22.549	96,976	$31.231
105mm	M494	33.626	19,223	33.626
106mm	M581	23.550	68,828	23.088

In order to normalize this data in terms of 105mm costs, the conversion factors developed in Table 28 were used. The average weighted unit APERS LAP cost of $28.451 is 1.4334 times the standardized LAP cost of HEAT rounds.

Complexity Factor 3 - In order to convert projected costs of APDS to TPDS projectiles, an analogy was made between the M724A1 105mm TPDS projectile and the M392A1 APDS projectile. The average cost of the M724A1 is $76.713. Since the M392A1 projectile has an average cost of $144.652, the M724A1 projectile is .5303 times as expensive as the APDS round. This complexity factor is utilized for converting an estimated APDS DU projectile to a TPDS projectile.

Complexity Factor 4 - A complexity factor of .6007 was developed to convert HEAT projectile theoretical first unit costs to WP projectile theoretical first unit costs. This was accomplished by comparing the average cost of the only WP tank round projectile on which data was available, the 105mm M416, to the normalized weighted average cost of HEAT projectiles in the data base. As was the case in the development of complexity factor 1, the obsolete M431 and M436 projectile costs were deleted. A normalized weighted average unit cost of $40.723 was developed using the same procedures described for complexity factor 1. The HE projectile CER: Ln Theoretical First Unit Cost FY 74 $ = -1.6983 + (1.3739 X Ln Bore Size) was used as the basis for the conversion, since no HEAT CER is available.

Complexity Factor 5 - A complexity factor of 3.8289 was derived to convert HEAT projectile theoretical first unit costs to APERS projectile theoretical first unit costs. The same methodology was utilized as for complexity factor 2. The normalized average cost of HEAT projectiles of $40.723 was compared to the normalized weighted average cost of APERS projectiles in the data base. This weighted cost of $155.926 is 3.8289 times the HEAT projectile cost.

4. THROUGHPUT

Other Explosive Elements

	105MM FY 77 $	120MM FY 77 $
HEAT		
Nitroguanidine	$ 7.101	
Liner	2.141	
Benite	1.542	
M13 Tracer	.593	
	$11.377	$17.185
Full Frontal Area Impact Switch	18.834	18.834
TOTAL	$30.211	$36.019
HEAT-TP		
Nitroguanidine	$ 7.101	
Liner	2.141	
Benite	1.542	
M13 Tracer	.593	
TOTAL	$11.377	$17.185
APDS		
Nitroguanidine	$ 7.101	
Benite	3.034	
Black Powder	.001	
M13 Tracer	.593	
Liner	1.929	
TOTAL	$12.658	$ 19.120

Other Explosive Elements

	105MM FY 77 $	120MM FY 77 $
TPDS		
Nitroguanidine	$ 5.471	
Benite	3.034	
Black Powder	.214	
M13 Tracer	.593	
Liner	2.084	
TOTAL	$11.396	$17.213
WP		
XM175 Burster	$12.903	
M48 Burster	1.367	
TNT	.053	
Comp. B.	.126	
Black Powder	.099	
M12 Tracer	2.270	
TOTAL	$16.818	$25.404
APERS		
XM86 Detonators	$ 3.805	
M7 Relay	.135	
M87 Detonators	.368	
M9 Propellant	.198	
M13 Tracer	.593	
TOTAL	$ 5.099	$ 7.702

V. REFERENCES

1. Ammunition Cost Research Study, Gerald W. Kalal and Patrick Gannon, Jun 76, AD-A-029330.

2. Ammunition Cost Research: Medium-Bore Cannon Ammunition, Annexes A-E, Patrick Gannon, Celestino George, Gerald Kalal, Kathleen Keleher, Paul Riedesel, Joseph Robinson, Sep 75, AD-A-016104.

3. Cost Estimating Relationships for Manufacturing Hardware Cost of Gun/Howitzer Cannons, Gerald W. Kalal, Aug 72, AD-75-7163.

4. ARRCOM Regulation 37-24, Financial Administration: Inflation and Price Escalation Instructions, 16 Mar 77.

5. DF, DRSAR-CPE, 14 Oct 77, subject: Inflation Guidance.

6. DF, DRSAR-CPE, 20 Oct 77, subject: Inflation Guidance.

7. Letter, SARWV-PPN, 2 Nov 77, subject: XM1 Tank Main Armament Evaluation.

8. FONECON between Frederick J. Northey, DRSAR-SAA, and Joseph Robinson, DRSAR-CPE, 8 Nov 77, subject: Input Data for Independent Unit Cost Assessment; RE: XM1 TMAE CSLS Impact Evaluation.

9. Class V Report: Estimated Replacement Prices (Ammunition) Based on Current Average Costs Plus Adjustments, 31 Aug 77, RIN P02CM10234M.

10. Wholesale Prices and Price Index Supplement 1972, US Department of Labor, Bureau of Labor Statistics, Feb 73.

11. Wholesale Prices and Price Index Supplement 1977, US Department of Labor, Bureau of Labor Statistics, Oct 77.

12. DF, DRSAR-SAL, 11 Oct 77, subject: XM1 Tank Main Armament Evaluation.

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13. ABSTRACT

Parametric estimating of the recurring investment costs for tank main armament systems has recently been improved with new modeling techniques, as well as with an improved data base. This report illustrates the use of such estimating techniques as prepared for the XM1 Tank Main Armament Evaluation (TMAE). It also expands parametric estimating techniques to white phosphorous (WP), antipersonnel (APERS), and target practice discarding sabot (TPDS) rounds.

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Ammunition Cost Estimating						
Transportation of Ammunition						
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Cost Model						
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Parametric Cannon Estimates						
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